Seismic Vulnerability Assessment of Plaza Bogor Building in Bogor City

Muhamad Lutfi, Nurul Chayati, Indra Muliyana, Muhammad Khaerul Insan

Civil Engineering Department at Ibn Khaldun University Bogor, INDONESIA

E-mail: mlutfi@ft.uika-bogor.ac.id

ABSTRACT

Plaza Bogor Building is a commercial building that is the center of economic activity that has been established for 28 years, it is important to conduct a structural vulnerability analysis to ensure the strength of the building structure is able to withstand potential earthquakes that can occur again at any time. This study aims to assess the level of vulnerability of the Plaza Bogor Building structure to earthquakes using the Rapid Visual Screening (RVS) method based on FEMA P-154 2015 and testing the quality of concrete using the Hammer Test method, and structural analysis using ETABS v.21 software to evaluate the performance of the Plaza Bogor Building structure against earthquake loads based on performance-based methods. The analysis results show that the final RVS value of the Plaza Bogor Building does not experience damage of 99,874% against earthquakes. All structural elements of the columns, beams, and slabs of the Plaza Bogor Building that have been tested with the Hammer Test get the value of concrete quality on the basement floor column to the fourth floor in the range of 41,55MPa – 57,10MPa, the value of concrete quality on the first floor beam to the fourth floor in the range of 41,61MPa – 51,98MPa, and the value of concrete quality on the first floor slab to the fourth floor in the range of 51,57MPa – 57,10MPa where the value meets the fc' >21MPa standard based on SNI 2847:2019. The results of the analysis of the upper structure of the Plaza Bogor Building against static earthquake loads and dynamic earthquake loads in the ETABS program show that there are eleven out of 906 beams that experience overstress and there are two out of 511 columns that experience overstress, so the safety of structural elements in the Plaza Bogor Building is 99,08% against earthquakes.

Keywords: structural vulnerability, rapid visual screening, concrete, and earthquake.

INTRODUCTION

In mitigating the impact of natural disasters, especially earthquakes, since Bogor City is categorized into earthquake zone 4 [1], assessing the vulnerability level of building structures is very important, especially for commercial buildings such as Plaza Bogor. As a commercial building that is the center of economic activity and has been standing for 28 years. Plaza Bogor Building has not experienced a fire but has experienced several earthquakes [2], so it is important to ensure the strength of the building structure is able to withstand potential earthquakes that can occur again at any time. An assessment of the vulnerability level of the building structure can identify the strengths and weaknesses of the structure and provide recommendations for necessary structural repairs or reinforcement [3]. The Rapid Visual Screening (RVS) method based on FEMA P-154 2015 is a rapid assessment method designed to evaluate the vulnerability of buildings to earthquakes based on visual observations and several key structural parameters. As well as modeling of performance-based structural design and analysis that focuses on the actual performance of building structures during natural disasters such as earthquakes, so as to determine the serviceability of building buildings and the level of reliability of building structures [4].

Some of the main factors causing technical building vulnerability include location, topography, soil bearing capacity, use of building materials that do not meet specifications and inadequate buildings located in earthquake areas [5]. Simple residential buildings must meet the technical requirements set out in Law no.28 of 2002 on building construction. In the city of Bogor there are areas that have the potential for landslides and land movement that can threaten the safety of its residents [6]. The vulnerability of a building is the inability of the building to withstand shaking due to a certain level

of earthquake strength that is expected to occur [7]. Vulnerability is a series of conditions that determine whether hazards (both natural and man-made hazards) that occur will be able to cause a disaster or not [8].

Earthquake load is a load that occurs naturally due to movement in the soil layer so that there is an acceleration in the soil that causes loads on the structure due to soil interaction with the structure and structural response characteristics. Earthquake loads arise due to acceleration so that the greater the weight of the structure, the greater the earthquake load received by the structure [19]. Based on SNI 1726:2019, the plan earthquake load is determined as an earthquake with the possibility of exceeding its magnitude during the 50-year life of the building structure by 2%. To design an earthquake-resistant building structure, we must consider various things, one of which is the main factor and risk category of the building structure [20].

Buildings constructed with concrete are widely recognized for their exceptional durability and long service life. Concrete is a composite material made primarily of cement, water, and aggregates such as sand and gravel. When mixed and properly cured, it undergoes a chemical reaction known as hydration, forming a hard, stone-like mass that can withstand substantial loads and environmental stresses. This intrinsic strength is one of the primary reasons why concrete has been used for centuries in infrastructure, residential buildings, and monumental structures around the world [21]. One of the key characteristics that makes concrete buildings durable is their high compressive strength. Concrete performs extremely well under compression, allowing it to support heavy structural loads without significant deformation. When combined with steel reinforcement in reinforced concrete systems, the material also gains tensile strength, enabling it to resist bending and dynamic forces such as wind and earthquakes. The synergy between concrete and steel enhances structural integrity and ensures long-term performance even under demanding conditions [22].

RESEARCH METHOD
Materials

The stages carried out in the Seismic Vulnerability Assessment of Plaza Bogor Building in Bogor City are presented in the form of a flowchart in Figure 1 below.
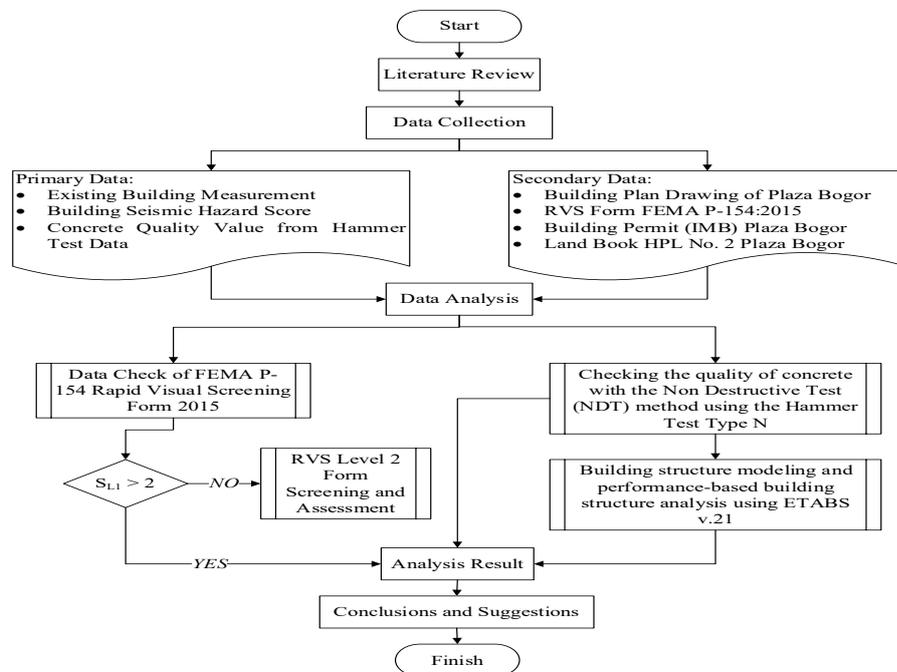

Figure 1. Research flowchart (*Source: Analysis result*)

This research begins with field survey preparation and the establishment of research objectives. A literature review is conducted to understand the concept of structural vulnerability and identify new contributions in this study. Data is collected in two forms: primary data through direct field measurements such as the hammer test and rapid visual screening (RVS), and secondary data from technical documents related to Plaza Bogor.

Methods

This research conducted at the Plaza Bogor Building located at Suryakencana Road No. 3, RT.03/RW.07, Babakan Pasar Village, Central Bogor Sub-district, Bogor City - West Java 16126 with latitude coordinates: -6,603601 and longitude: 106,799785. The research period started from September 2024 to April 2025. The research location layout is shown in Figure 2 below.
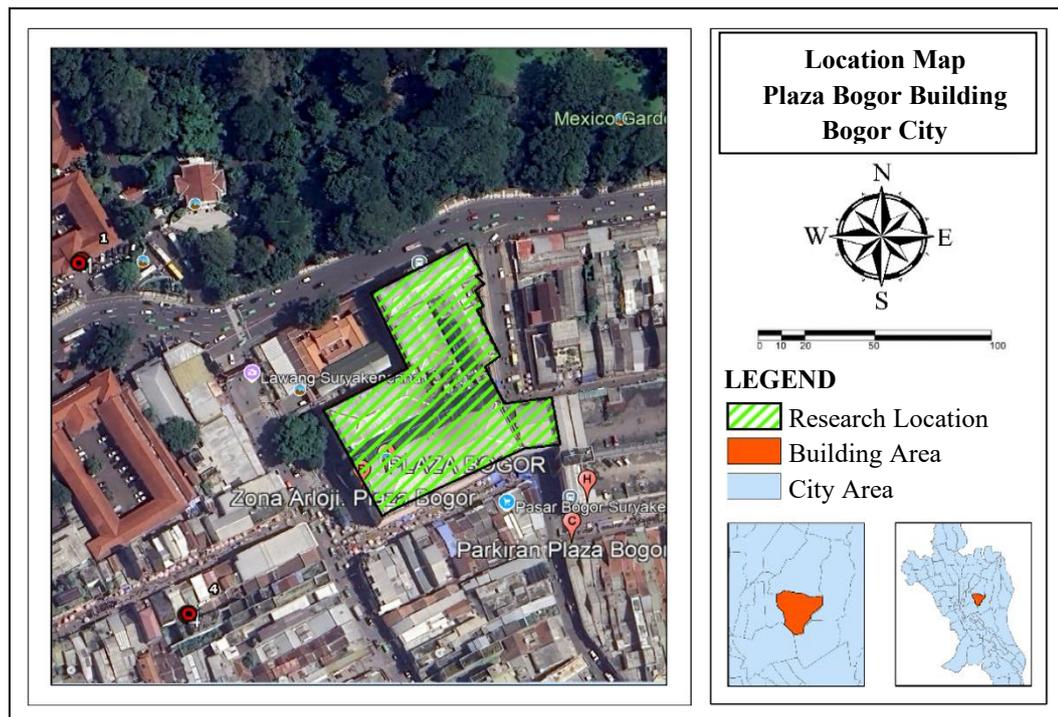

Figure 2. Plan of the research location (Source: Google Earth Pro)

This research was conducted to assess the structural vulnerability of the Plaza Bogor building to seismic activity in Bogor City. The research process begins with initial planning, which includes drafting the research plan, defining objectives, and identifying problems. A literature review is then conducted by gathering references related to structural assessment methods and standards such as FEMA P-154 (2015) and SNI 1726:2019. Data is collected from two main sources: primary data, including existing building measurements, building seismic hazard assessment, and concrete quality testing using the hammer test, and secondary data, such as Plaza Bogor floor plan drafts, Rapid Visual Screening (RVS) forms, Building Permit (IMB), and relevant publication databases. Data analysis is carried out through Rapid Visual Screening (RVS) for an initial assessment of building vulnerability, concrete quality testing using the Non-Destructive Test (NDT) method, and structural modeling and performance-based analysis using ETABS.

Data Analysis

Data analysis was conducted using statistical methods, FEMA P-154 RVS, and structural modeling and simulation with ETABS to evaluate the vulnerability level of the building. The results of the analysis assessed the safety of the structure based on regulations such as SNI 2847:2019 and SNI 1726:2019, by examining aspects of concrete quality, structural forces, and potential overstress in building elements. Conclusions and suggestions are then compiled as the basis for mitigation efforts

aimed at reducing the level of damage that the structure will experience during an earthquake and avoiding casualties or increasing the safety and security factors of the building.

RESULTS AND DISCUSSION

The building structure should be assigned a seismic design category based on SNI 1726-2019, Article 6.5 which states that structures with risk category I, II or III located where the spectral response parameter of the mapped acceleration at a period of 1 second (S_1) is greater than or equal to 0,75 should be assigned as structures with seismic design category E. Structures of risk category IV located where the mapped acceleration spectral response parameter at a period of 1 s (S_1) is greater than or equal to 0,75 shall be designated as structures of seismic design category F. All other structures shall be assigned a seismic design category based on their risk category and their design acceleration spectral response parameter. Structures should be assigned to the more severe seismic design category, with reference to Table 1 and Table 2, regardless of the value of the structure's fundamental period of vibration, (T). If an alternative simplified procedure is used the seismic design category is allowed to be determined from Table 1, using the S_{DS} values obtained in the RSA 2021 software.

Table 1. Seismic design categories based on short-period acceleration response parameters

S_{DS} Value	Risk category	
	I, II or III	IV
$S_{DS} < 0,167$	A	A
$0,167 \leq S_{DS} < 0,33$	B	C
$0,33 \leq S_{DS} < 0,50$	C	D
$0,50 \leq S_{DS}$	D	D

(Source: SNI 1726-2019, article 6.5, Table 8)

The seismic design categories based on the 1-second period acceleration response parameters are shown in the following Table 2.

Table 2. Seismic design categories based on acceleration response parameters at a period of 1 second

SDS Value	Risk category	
	I, II or III	IV
$S_{D1} < 0,067$	A	A
$0,067 \leq S_{D1} < 0,133$	B	C
$0,133 \leq S_{D1} < 0,20$	C	D
$0,20 \leq S_{D1}$	D	D

(Source: SNI 1726-2019, article 6.5, Table 8)

The following are the results of the assessment of the Bogor Plaza Building using the RVS form for the high seismicity category based on FEMA P-154 2015 which can be seen in the following Table 3.

Table 3. Final level 1 score of Plaza Bogor building

Category	Description
Vertical Irregularity	✓
Plan Irregularity	-
Building Type	C1
Basic Score	1,5
Severe Vertical Irregularity (VL1)	-
Moderate Vertical Irregularity (VL1)	-0,5
Plan Irregularity (PL1)	-
Pre-Code	-
Post Benchmark	1,9
Soil Type	D
Minimum Score (S_{min})	0,3

Category	Description
Final level 1 score S (S$_{L1}$)	**2,9**

(*Source: Analysis result based on FEMA RVS form P-154*)

Based on Table 3 The final level 1 score (S$_{L1}$) obtained is 2,9. If S$_{L1}$ ≤ 2, the building is declared to be at risk of earthquake threats and needs further evaluation. Next, the final score (S) analysis is carried out obtain a percentage of the potential vulnerability of the building to earthquakes in the Plaza Bogor Building as follows:

$$(S) = \frac{1}{10^{SL1}} = \frac{1}{10^{2,9}} = 0,00126$$

The calculation results obtained a final score (S) value 0,00126 so that the percentage of potential vulnerability in the Plaza Bogor Building is 0,126%, so if an earthquake occurs the building can be declared safe because the Plaza Bogor Building does not experience damage of 99,874% against earthquakes based on the results of the FEMA P-154 Rapid Visual Screening (RVS) 2015 assessment.

Based on the data from the concrete quality test results of the Bogor Plaza Building which has been analyzed, then it can be concluded by referring to SNI 2847:2019, all the results of the estimation of the compressive strength of concrete for column, beam and slab structural elements using the Hammer Test method can be seen in the Table 4 as follows.

Table 4. Recapitulation of concrete quality values for Plaza Bogor Building

No.	Structure Elements	Minimum Value		Maximum Value		Average	
		Kg/cm²	MPa	Kg/cm²	MPa	Kg/cm²	MPa
Basement Floor							
1.	Column	337,77	33,14	615,11	60,34	475,86	46,68
Ground Floor							
1.	Column	241,78	23,72	651,11	63,87	439,09	43,07
First Floor							
1.	Column	257,33	25,24	631,11	61,91	423,50	41,55
2.	Beam	341,78	33,53	584,00	57,29	448,57	44,00
3.	Slab	385,11	37,78	631,33	61,93	525,67	51,57
Second Floor							
1.	Column	349,44	34,28	671,11	65,84	562,99	55,23
2.	Beam	294,00	28,84	625,33	61,34	485,89	47,67
3.	Slab	456,89	44,82	633,33	62,13	573,81	56,29
Third Floor							
1.	Column	364,33	35,74	671,11	65,84	522,34	51,24
2.	Beam	458,89	45,02	619,33	60,76	529,90	51,98
3.	Slab	496,00	48,66	613,33	60,17	565,11	55,44
Fourth Floor							
1.	Column	339,44	33,30	631,11	61,91	491,63	48,23
2.	Beam	315,56	30,96	510,00	50,03	424,19	41,61
3.	Slab	481,56	47,24	633,33	62,13	582,09	57,10

(Source: Analysis result)

Based on Table 4 it can be concluded that all structural elements of the columns, beams, and slabs of the Plaza Bogor Building that have been tested for concrete quality with the Hammer Test obtained a value of fc' >21MPa which exceeds the limit of the fc' value in accordance with SNI 2847:2019, then the structural elements of the columns, beams, and slabs of the Plaza Bogor Building are capable of being used for special moment-bearing frame systems and special structural walls.

Structural analysis is the process of knowing the response of a building to the loads acting on the structural system by conducting structural analysis on existing buildings, it can assess the actual condition of the structure, determine the capacity of structural elements, and determine whether the building still meets applicable safety and comfort standards. In addition, this analysis also helps in

identifying potential structural damage or weaknesses, evaluating the need for repair or reinforcement, and ensuring optimal building performance against working loads, such as gravity loads, earthquakes, and additional loads which refers to SNI 1727:2020.

The seismic force-bearing system is designed to withstand lateral loads due to earthquakes so, the selection of this system is very important to ensure that the building has sufficient resistance to earthquakes in accordance with SNI 1726:2019. The earthquake value in Bogor City can be known directly shown on Figure 3 images obtained from the coordinates of the Plaza Bogor Building, then inputted using the Indonesian Design Response Spectrum 2021 PuSGeN software, DBTPP, Directorate General of Human Settlements, Ministry of PUPR.
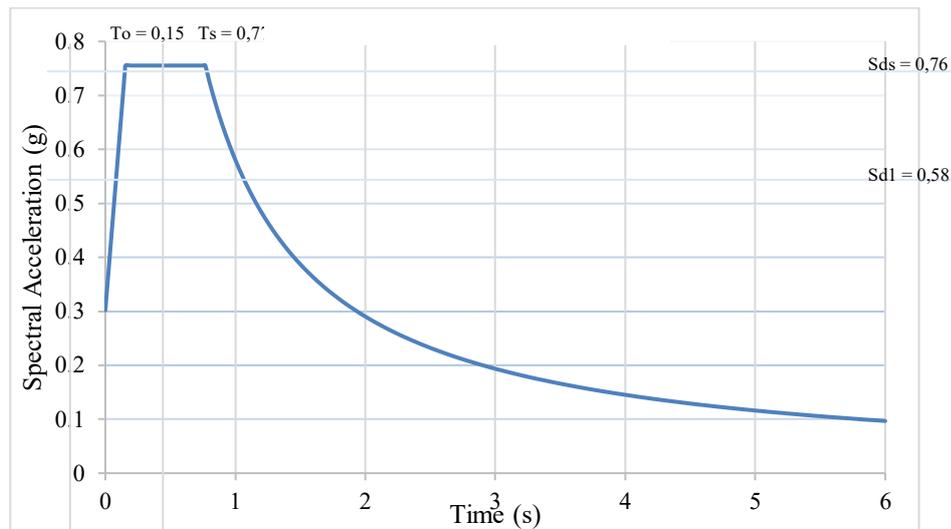

Figure 3. Acceleration spectral graph (g) (Source: RSA software, 2021)

The risk category for the Plaza Bogor Building is II and the seismic design category is D. So that the seismic force bearing system can be determined based on Table 12 - SNI 1726:2019 including the Special Moment Bearing Frame System (SRPMK). The following summary of seismic force bearing system data for the Bogor Plaza Building is shown in Table 5.

Table 5. Summary of seismic force resisting system data

Parameters	Notation	Value
Spectral short-period acceleration	S_1	0,478g
Spectral acceleration of 1-second period	S_S	1,049g
Short-period design acceleration	S_{DS}	0,755g
1 second period design acceleration	S_{D1}	0,581g
Transition period	T_L	20,000s
Risk category		II
Earthquake primacy factor	I_e	1,000
Seismic design category	KDS	D
Seismic force resisting system		SRPMK
Response modification coefficient	R	8,000
Strong factor over system	Ωo	3,000
Deflection magnification factor	C_d	5,500

(Source: Analysis result)

The main elements of the upper structure of a building consist of columns, beams, and plates. The main elements are modeled using ETABS software in accordance with the draft drawing of the Bogor Plaza Building plan obtained from Perumda Pasar Pakuan Jaya of Bogor City. Then the modeling of the main elements of the Bogor Plaza Building structure is given a loading that refers to SNI 1727:2020. The loading given to the Plaza Bogor Building structure model includes gravity loads such as dead loads on the floor slab structure shown in the following Table 6.

Table 6. Dead load on floor slab structure

Material Type	Weight (kN/m²)
Ceramics and specs	1,10
Plafond	0,05
Hanger	0,10
Mechanical ducting	0,19
Total	**1,44**

(Source: SNI 1727:2020 Table C3.1-1 - Minimum design dead load)

The loading given to the Bogor Plaza Building structural model includes gravity loads such as dead loads on the roof slab structure shown in the following Table 7.

Table 7. Dead load on roof slab structure

Material Type	Weight (kN/m²)
Waterproofing layer	0,05
Plafond	0,05
Hanger	0,10
Mechanical ducting	0,19
Total	**0,39**

(Source: SNI 1727:2020 Table C3.1-1 - Minimum design dead load)

The loading given to the Bogor Plaza Building structural model includes gravity loads such as dead loads on the roof truss structure shown in the following Table 8.

Table 8. Dead load on roof truss structure

Component	Description	Weight (kN/m)
Roof truss	4m × 0.96kN/m²	3,84
Total		**3,84**

(Source: SNI 1727:2020 Table C3.1-1 - Minimum design dead load)

The loading given to the Bogor Plaza Building structural model includes gravity loads such as dead loads on the floor beam structure shown in the following Table 9.

Table 9. Dead load on floor beam structure

Component	Description	Weight (kN/m)
Red brick and plaster wall	4m × 2.5 kN/m²	10,00
Total		**10,00**

(Source: SNI 1727:2020 Table C3.1-1 - Minimum design dead load)

The loading given to the Bogor Plaza Building structural model includes gravity loads such as dead loads on the slab structure shown in the following Table 10.

Table 10. Live load on slab structure

Live Load Type	Average Weight (kN/m²)
All residential and ground floor retail uses	4,79
All residential and retail uses of the floor above	3,59
All residential and grocery store uses on all floors	6,00
Flat roof slab area load	0,96

(Source: SNI 1727:2020 Table 4.3-1 (Continued) - Minimum uniformly distributed live load, L_o and minimum centralized live load)

After all the loadings have been inputted in the ETABS software, where each loading is inputted, the structure that has been designed can be carried out at the next stage, namely the run analysis stage shown in Figure 4.
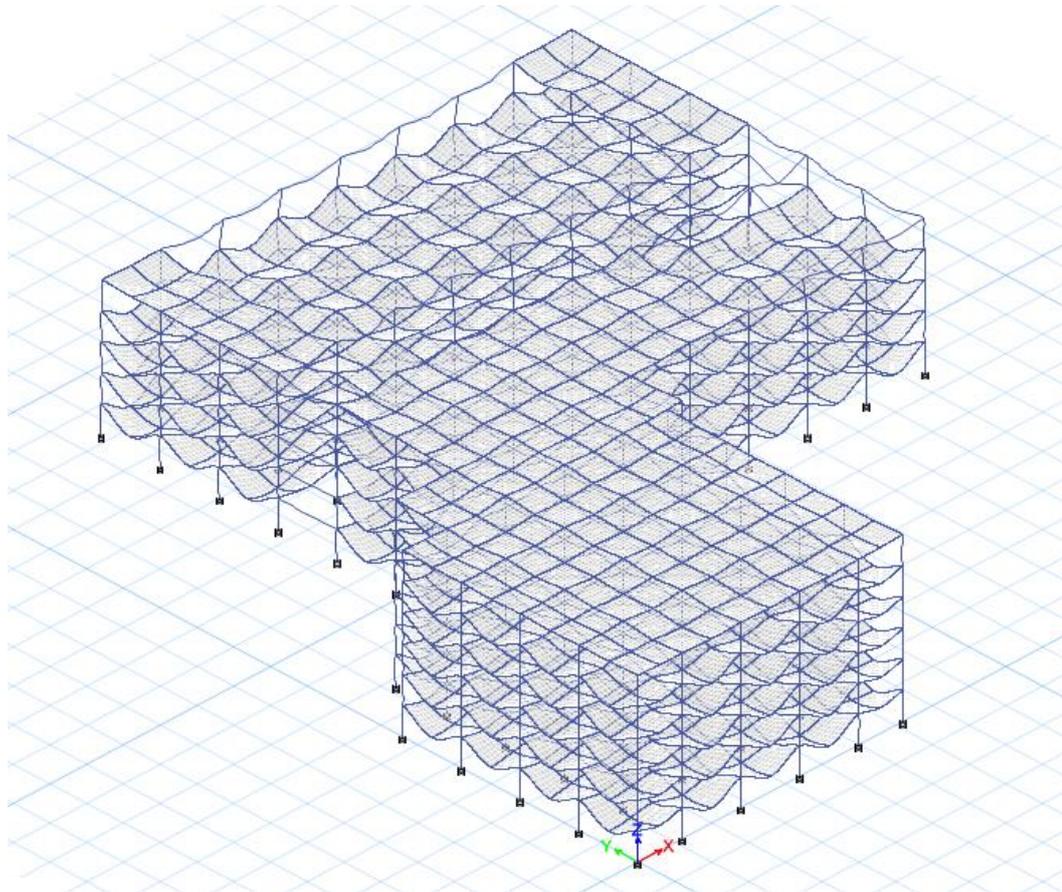
Figure 4. Results of dead load displacements (Source: Analysis result)

Based on SNI 1726:2019 the value of the fundamental period of the approach structure (Ta) is determined by processing data on the period limit coefficient and building height. Based on article 7.8.2, Table 17 and article 7.8.2.1, Table 18 in SNI 1726:2019, the coefficient values C_u; C_t; and x are 1,4; 0,0466; and 0,9. The height of the Plaza Bogor Building is 2400mm. So that the minimum Ta, maximum Ta, and T values of the building are obtained in the ETABS software for each x direction and y direction shown in Table 11.

Table 11. Values of fundamental vibrating period of the structure

Period	X direction (sec)	Y direction (sec)
Ta minimum	0,814	0,814
Ta maximum	1,139	1,139
T building	1,601	1,487
Value	1,139	1,139

(Source: Analysis result)

The fundamental vibrating period value of the building structure generated by ETABS software for the X direction is 1,601 and for the Y direction is 1,487. These values are outside the minimum and maximum limits, so the middle value is between the minimum Ta value and the T value of the building. Vibration patterns in modes 1, 2, and 3 are shown in the following **Error! Reference source not found.** to **Error! Reference source not found.**.
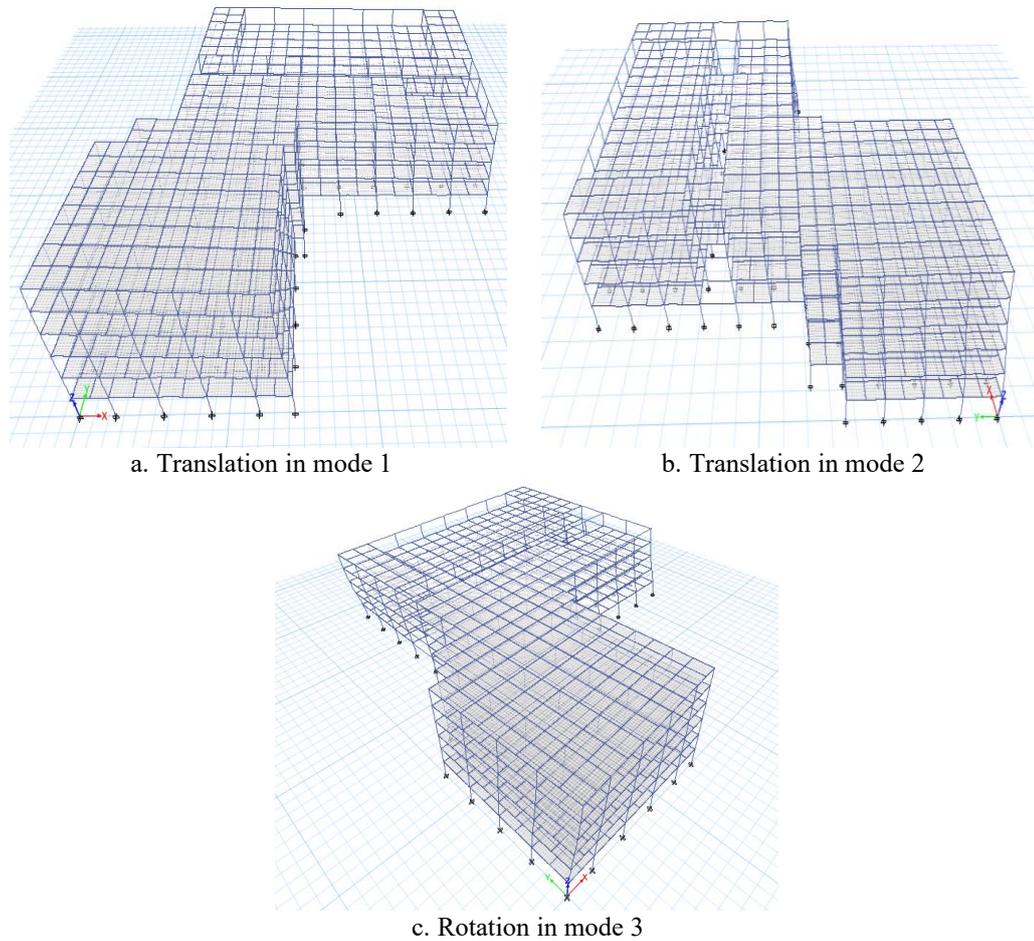
a. Translation in mode 1

b. Translation in mode 2

c. Rotation in mode 3

Figure 5. Vibration mode patterns of the building structure (Source: Analysis result)

In Figure 5a that has been presented, we can see the vibration pattern (mode 1) of the building structure that is translated towards the x-axis with a period of 1,601 seconds. Figure 5b is a pattern of vibration (mode 2) in the structure of the building that experiences translation towards the y-axis with a period of 1,487 seconds. While in Figure 5c is a pattern of vibration (mode 3) in the structure of the building that undergoes rotation towards the z-axis with a period of 1,381 seconds. So that the shape of the variation pattern meets the standards for stiffness in building structures.

Based on SNI 1726:2019 to determine the natural vibration variation of the structure, the analysis must include a sufficient number of variations to obtain a permitted mass participation of the combined variations of at least 90% of the actual mass in each orthogonal horizontal direction of the response reviewed by the model. The mass participation values are shown in the following Table 12.

Table 12. Mass participation values of each mode

Mode	Period (seconds)	UX	UY	SumUX	SumUY
1	1,601	0,2650	0,1819	0,2650	0,1819
2	1,487	0,2105	0,5586	0,4756	0,7405
3	1,381	0,3223	0,0499	0,7978	0,7905
4	0,488	0,0385	0,0246	0,8363	0,8150
5	0,452	0,0286	0,0834	0,8649	0,8984
6	0,412	0,0453	0,0057	0,9102	0,9042
7	0,335	1,05E-06	0,0010	0,9102	0,9052

Mode	Period (seconds)	UX	UY	SumUX	SumUY
8	0,275	0,0103	0,0014	0,9205	0,9066
9	0,271	0,0023	0,0012	0,9228	0,9078
10	0,261	4,728E-05	0,0026	0,9229	0,9104
11	0,256	0,0004	0,0219	0,9233	0,9323
12	0,253	0,0004	0,0085	0,9237	0,9408

(Source: Analysis result)

Based on Table 12 , it can be seen that the mass participation in the x-direction has met the minimum requirement of 90%, which was achieved in the 6th mode with a value of 91,02%. Meanwhile, mass participation in the y-direction has also met the minimum requirement of 90%, which was achieved in the 6th mode with a value of 90,42%.

Deflections can serve to assess the safety of a building in the face of earthquake forces. Lateral deviations between floors (story drift) should always be checked to ensure structural stability, prevent damage to building elements, and ensure comfort for occupants. The calculation of inter-story drift at the design level should be done by calculating the difference in deflection between the center of mass at the top and bottom floors being analyzed. The x-direction inter-story drift control is shown in the following Table 13.

Table 13. Control of x-direction inter-story drift

Story	X-Dir (mm)	Displacement (mm)	Story Drift (mm)	Story Drift Clearance Δa	Story Drift < Δa
Deck Floor	100,991	9,712	53,416	80	*Ok*
4th floor	91,279	15,700	86,350	80	*Not Ok*
3rd floor	75,579	20,866	114,763	80	*Not Ok*
2nd floor	54,713	23,098	127,039	80	*Not Ok*
1st floor	31,615	20,751	114,131	80	*Not Ok*
Ground Floor	10,864	10,864	59,752	80	*Ok*

(Source: Analysis result)

The y-direction inter-story drift control is shown in the following Table 14.

Table 14. Control of y-direction inter-story drift

Story	Y-Dir (mm)	Displacement (mm)	Story Drift (mm)	Story Drift Clearance Δa	Story Drift < Δa
Deck Floor	97,814	10,250	56,375	80	*Ok*
4th floor	87,564	16,486	90,673	80	*Not Ok*
3rd floor	71,078	22,204	122,122	80	*Not Ok*
2nd floor	48,874	23,564	129,602	80	*Not Ok*
1st floor	25,310	17,299	95,145	80	*Not Ok*
Ground Floor	8,011	8,011	44,061	80	*Ok*

(Source: Analysis result)

Based on Table 13 and Table 14, it is known that the floor deviation values of the Bogor Plaza Building structure on the 1st, 2nd, 3rd, and 4th floors exceed the permissible story drift regulated in SNI 1726:2019. When the deviation between floors does not meet the requirements, the structure must be made more rigid by adding shear walls and increasing the portal dimensions.

Results of structural analysis with ETABS software The results of structural analysis with ETABS software, namely with concrete frame design, are shown in Table 15 shows eleven main beams on the second floor that experienced structural failure or overstress with O/S code #45 Shear stress due to shear force and torsion together exceeds maximum allowed which means that shear stress due to a combination of shear and torsion forces together exceeds the maximum allowed limit, and two columns on the ground floor that experienced structural failure or overstress with O/S code #2

Reinforcing required exceeds maximum allowed and Warning #34 Joint shear ratio exceeds limit, meaning that the column reinforcement requirement exceeds the maximum limit. Therefore, the dimension of the column section needs to be enlarged. Thus the solution is to do structural reinforcement such as methods like:

1. FRP Wrapping (Fiber Reinforced Polymer) is wrapping elements with carbon fiber to increase shear and torsional capacity.
2. Concrete jacketing is adding a layer of concrete and additional reinforcement around weak elements.
3. Steel Jacketing is lining an element with steel plates to increase shear and torsional capacity.

Table 15. Concrete frame design

No.	Structure Elements	Description
1.	B.B12	O/S #45 Shear stress due to shear force and torsion together exceeds maximum allowed
2.	B.C12	O/S #45 Shear stress due to shear force and torsion together exceeds maximum allowed
3.	B.D12	O/S #45 Shear stress due to shear force and torsion together exceeds maximum allowed
4.	B.B56	O/S #45 Shear stress due to shear force and torsion together exceeds maximum allowed
5.	B.C56	O/S #45 Shear stress due to shear force and torsion together exceeds maximum allowed
6.	B.D56	O/S #45 Shear stress due to shear force and torsion together exceeds maximum allowed
7.	B.E56	O/S #45 Shear stress due to shear force and torsion together exceeds maximum allowed
8.	B.3EF	O/S #45 Shear stress due to shear force and torsion together exceeds maximum allowed
9.	B.G1011	O/S #45 Shear stress due to shear force and torsion together exceeds maximum allowed
10.	B.4KL	O/S #45 Shear stress due to shear force and torsion together exceeds maximum allowed
11.	B.10KL	O/S #45 Shear stress due to shear force and torsion together exceeds maximum allowed
12.	K.G3	O/S #2 Reinforcing required exceeds maximum allowed Warning #34 Joint shear ratio exceeds limit
13.	K.G4	O/S #2 Reinforcing required exceeds maximum allowed Warning #34 Joint shear ratio exceeds limit

(Source: Analysis result)

CONCLUSION

Based on the analysis of the structural vulnerability of Plaza Bogor Building to static and dynamic earthquake loads, it can be concluded that the building has a high level of safety against earthquakes. The calculation results show a final score (S) of 0.00126, indicating a vulnerability potential of 0.126%, meaning the building is considered safe with a 99.874% resistance to earthquakes based on the Rapid Visual Screening (RVS) method from FEMA P-154 (2015). Concrete quality testing using the Hammer Test shows that all structural elements, including columns, beams, and slabs, have an fc' value exceeding 21MPa, which meets the requirements of SNI 2847:2019, making them suitable for use in special moment-resisting frames and special structural walls. Structural analysis using ETABS reveals that out of 906 analyzed beams, eleven experience overstress, while two out of 511 columns also experience overstress. Consequently, the structural elements of Plaza Bogor Building maintain a 99.08% level of safety against earthquakes. To enhance structural resilience, the overstressed elements can be strengthened using methods such as FRP Wrapping (Fiber Reinforced Polymer), Concrete Jacketing, or Steel Jacketing. These findings conclude that while Plaza Bogor

Building is generally safe against earthquakes, reinforcement of certain structural elements is still necessary to optimize its overall strength and safety.

ACKNOWLEDGEMENT

REFERENCE

[1] Afrianto Budi. (2024). 'Daftar Zona Gempa Indonesia', AkademiAsuransi. Accessed: Sep. 27, 2024. [Online]. Available: https://www.akademiasuransi.org/2013/01/daftar-zona-gempa-indonesia.html

[2] Perumda Pasar Pakuan Jaya (2024). 'Plaza Bogor'. Accessed: Sep. 27, 2024. [Online]. Available: https://www.pasarpakuanjaya.co.id/pasar/info/58000525630205658899

[3] FEMA P-154. (2015). 'Rapid visual screening of buildings for potential seismic hazards: FEMA 154 and FEMA 155 updates', *NCEE 2014 - 10th U.S. National Conference on Earthquake Engineering: Frontiers of Earthquake Engineering*, doi: 10.4231/D3M90238V.

[4] Indonesia. (2002). 'Undang-Undang Republik Indonesia Nomor 28 Tahun 2002 Tentang Bangunan Gedung Dengan Rahmat Tuhan Yang Maha Esa Presiden Republik Indonesia', Jakarta.

[5] R. Z. T. K. S. P. I. M. Heri Zulfiar. (2014). 'Identifying of Dominant Factor Cause of Building Vulnerability in The Earthquake Prone Area, West Sumatra Province.

[6] M. Lutfi, H. Arien, M. Hendrawati, P. J. Ramadhansyah, and N. I. Ramli. (2020). 'Assessment of safety performance level on simple urban residential building: Case study at Bogor city Indonesia', in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing. doi: 10.1088/1757-899X/712/1/012004.

[7] M. Lutfi and R. Suryawani. (2020). 'Penilaian Tingkat Kerentanan Bangunan Gedung Di Area Sekolah SIT Aliya Bogor', *Jurnal Manajemen Aset Infrastruktur & Fasilitas*, vol. 4, no. 4, pp. 1–12, doi: 10.12962/j26151847.v4i4.7912.

[8] Pusat Pendidikan Mitigasi Bencana. (2024). 'Rangkuman Geografi Kelas 11 Mitigasi Bencana'. Accessed: Sep. 28. [Online]. Available: https://www.gurugeografi.id/2021/05/rangkuman-geografi-kelas-11-mitigasi.html

[9] Badan Standardisasi Nasional. (1997). 'Standar Nasional Indonesia (SNI 03-4430:1997) tentang Metode Pengujian Elemen Struktur Beton dengan Alat Palu Beton Type N dan NR', BSN. Jakarta.

[10] Badan Standardisasi Nasional. (2012). 'Standar Nasional Indonesia (SNI ASTM C805:2012) tentang Metode Uji Angka Pantul Beton Keras', BSN. Jakarta,

[11] Badan Standardisasi Nasional. (2019). 'Standar Nasional Indonesia (SNI 2847:2019) tentang Persyaratan Beton Struktural Untuk Bangunan Gedung dan Penjelasan', BSN. Jakarta.

[12] Badan Standardisasi Nasional (2019). 'Standar Nasional Indonesia (SNI 1726:2019) tentang Tata Cara Perencanaan Ketahanan Gempa Untuk Struktur Bangunan Gedung dan Non Gedung', BSN. Jakarta.

[13] Badan Standardisasi Nasional. (2020). 'Standar Nasional Indonesia (SNI 1727:2020) tentang Beban Desain Minimum dan Kriteria Terkait Untuk Bangunan Gedung dan Struktur Lain', BSN. Jakarta.

[14]   Lutfi, M., Chayati, N., Rulhendri, R. (2022). 'Assessment of building seismic risk in the environment of Ibn Khaldun University Bogor', 11(3), pp. 517–525.

[15]   Lutfi, M., Chayati, N., Witarsa, A. (2022). 'Penilaian Tingkat Kerentanan Bangunan RSPG Cisarua Bogor dengan Menggunakan Metode Rapid Visual Screening (RVS)', Jurnal Komposit: Jurnal Ilmu-ilmu Teknik Sipil, 6(2), pp. 73–80. Available at: https://doi.org/10.32832/komposit.v6i2.7168

[16]   Lutfi, M. (2023). 'Development of the structure of the Jamie Nurul Iman Sukaraja Mosque building based on the needs of congregation facilities', 12(1), pp. 63–076. Available at: https://doi.org/10.32832/astonjadro.v12i1.

[17]   Lutfi, M. (2024). 'Structural Analysis of one-Block Compartment Building in Sentul Indah Residence Housing', 13(3), pp. 665–674. Available at: https://doi.org/10.32832/astonjadro.v13i3.

[18]   Pemerintah Kota Bogor. (2024). 'Kondisi Geografis Kota Bogor', Available at: https://kotabogor.go.id/index.php/page/detail/120/(Accessed: 27 September 2024).

[19]   Anwar, R. R., Pratikso, P., Wibowo, K., Taufik, S., & Setiawan, I. (2025). Integration of Design and Construction Implementation of Buildings on Soft Soil: Decision Support System Model Approach. ASTONJADRO, 14(3), 844–855. https://doi.org/10.32832/astonjadro.v14i3.18099

[20]   S Syaiful. (2020). Analysis on the Addition of Fiber the Strong Bending Mixed Concrete. ARPN Journal of Engineering and Applied Sciences 15 (6), 724-729.

[21]   Amrullah, A., Erniati, E., & Chaerul, M. (2021). Building Protection Design in Fire Hazard Prevention (Case Study: Fajar University Building (UNIFA) MAKASSAR). ASTONJADRO, 11(1), 50–60. https://doi.org/10.32832/astonjadro.v11i1.5669

[22]   S Syaiful. (2021). Additional Betonmix to Increase the Strength of Concrete Press. ARPN Journal of Engineering and Applied Sciences 16 (15), 1583-1589.